ABSTRACT

Aerosols affect the global radiation budget which plays an important role in determining the state of the Earth's climate. The heterogeneous distribution of aerosols and the variety in their properties results in high uncertainty in the understanding of aerosols. Aerosols affect the radiation by scattering and absorption (direct effect) or by modifying the cloud properties which in turn affects the radiation (indirect effect). The current work focuses only on the direct radiative effect of aerosols.

The change in the top-of-atmosphere (TOA) reflected flux due to the perturbation of aerosols and their properties is called direct aerosol radiative forcing (ARF_{TOA}). Estimation of ARF_{TOA} using aerosol properties is done by solving the radiative transfer equation using a radiative transfer model. However, before using the radiative transfer model, it has to be validated with observations for consistency. This is done to check if the model is able to replicate values close to actual observations. The current work uses the Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) model. The output radiative fluxes from SBDART are validated by comparing with the Clouds and the Earth's Radiant Energy System (CERES) satellite data. Under clear-skies SBDART agreed with observed fluxes at TOA well within the error limits of satellite observations.

In the shortwave solar spectrum (0.25-4 μm) radiation is affected by change in various aerosol properties and also by water vapour and other gas molecules. To study the effect of each of these molecules separately on the aerosol forcing at TOA, SBDART is used. ARF_{TOA} is found to depend on the aerosol loading (aerosol optical depth – AOD), aerosol type (SSA) and the angular distribution of scattered radiation (asymmetry parameter). The

role of water vapour relative to the aerosol layer height was also investigated and for different aerosol types and aerosol layer heights, it was found that water vapour can induce a change of ~4 Wm^{-2} in TOA flux.

The relative importance of aerosol scattering versus absorption is evaluated through a parameter called single scattering albedo (SSA) which can be estimated from satellites. SSA defined as the ratio of scattering efficiency to total extinction efficiency, depends on the aerosol composition and wavelength. Aerosols with SSA close to 1 (sea-salt, sulphates) scatter the radiation and cool the atmosphere. Aerosols with SSA < 0.9 (black carbon, dust) absorb radiation and warm the atmosphere. Over high reflective surfaces a small change in SSA can change forcing from negative (cooling) to positive (warming). This makes SSA one of the most important and uncertain aerosol parameters. Currently, the SSA retrievals from the Ozone Monitoring Instrument (OMI) are highly sensitive to sub-pixel cloud contamination and change in aerosol height. Using the sensitivity of OMI to aerosol absorption and the superior cloud masking technique and accurate AOD retrieval of Moderate Resolution Imaging Spectroradiometer (MODIS), an algorithm to retrieve SSA (OMI-MODIS) was developed. The algorithm was performed over global oceans (60S-60N) from 2008-2012. The difference in SSA estimated by OMI-MODIS and that of OMI depended on the aerosol type and aerosol layer height. Aerosol layer height plays an important role in the UV spectrum due to the dominance of Rayleigh scattering. This was verified using SBDART which otherwise would not have been possible using just satellite observations. Both the algorithms were validated with cruise measurements over Arabian Sea and Bay of Bengal. It was seen that when absorbing aerosols (low SSA values) were present closer to the surface, OMI overestimated the value

of SSA. On the other hand OMI-MODIS algorithm, which made no assumption on the aerosol type or height, was better constrained than OMI and hence was closer to the cruise measurements.

The presence of clouds results in a more complex interaction between aerosols and radiation. Aerosols present above clouds are responsible to most of the direct radiative effect in cloudy regions. The ARF_{TOA} depends not only on the aerosol properties but also on the relative position of aerosols with clouds. When absorbing aerosols are present above clouds, the ARF_{TOA} is highly influenced by the albedo of the underlying surface. Recent studies, over regions influenced by biomass burning aerosol, have shown that it is possible to define a 'critical cloud fraction' (CCF) at which the aerosol direct radiative forcing switch from a cooling to a warming effect. Similar analysis was done over BoB (6.5-21.5N; 82.5-97.5E) for the years 2008-2011. Aerosol properties were taken from satellite observations. Satellites cannot provide for aerosols present at different heights and hence SBDART was used to calculate the forcing due to aerosols present only above clouds. Unlike previous studies which reported a single value of CCF, over BoB it was found that CCF varied from 0.28 to 0.13 from post-monsoon to winter as a result of shift from less absorbing to moderately absorbing aerosol. This implies that in winter, the absorbing aerosols present above clouds cause warming of the atmosphere even at low cloud fractions leading to lower CCF.

The use of multiple satellites in improving the retrieval of SSA has been presented in this thesis. The effect of aerosols present above clouds on the radiative forcing at TOA is shown to be different between Bay of Bengal and Atlantic Ocean. This was due to the change in SSA of aerosols during different seasons. The effect of aerosol height, aerosol type and water vapour on the TOA flux estimation is also studied using a radiative transfer model.